# A Multi-scale Analysis Linking Prairie Breeding Birds to Site and Landscape Factors Including USGS GAP Data

Prepared for:

United States Department of the Interior
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Prepared by:

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# Executive Summary

Grassland and shrub-steppe bird populations have experienced more substantial declines during the last century than any other groups of birds throughout North America. Our study area in Southeast Montana has abundant natural habitat for these birds but invasive plant species, agricultural conversion, and energy development are altering natural conditions in the area and may affect this group of declining birds. We sampled 116 locations in southeast Montana for breeding bird presence during early summer 2007. A primary goal was to better document the distribution and abundance of this bird group in the study area. Another objective was to relate breeding bird presence, with an emphasis on Montana Species of Concern, to site and landscape factors so managers may better focus limited resources.

Site vegetation and ground cover characteristics were directly measured at each sampling site. Landscape variables were derived for three landscape scales as measured in 200 m, 800 m, and 5,000 m radius circles around the sampling point. USGS GAP land cover data was aggregated into a few general classes and several other landscape variables (measures of roads, watercourses, human populations, energy leases, wetlands, topographic roughness, etc.) were derived from other GIS data sources.

A univariate analysis compared differences in site ground cover and vegetation characteristics to the presence of six grassland and five shrubland bird species, six of which (four grassland and two shrubland species) are Montana Species of Concern (SOC). For the six SOC birds we additionally used logistic regression and non-metric multidimensional scaling ordination to analyze how these birds responded to site and landscape factors at 200, 800, and 5,000 m scales. The importance of site or landscape factors varied with individual species. Site factors may be more important for some species (e.g. Brewer's Sparrow, *Spizella breweri*), and landscape factors for others (e.g. Sprague's Pipit, *Anthus spragueii*). For other species, there was a more balanced response to site and landscape factors.

Site variables, especially grass density, maximum vegetation height, and maximum sagebrush height, appeared to be strongly related to the presence of particular bird species on point counts, although the presence of some species was also related to site landcover variables (% bare ground, % grass cover, % sage canopy). Grassland species tended to occur at sites with shorter and less dense grass. Shrubland species tended to occur at sites with taller sagebrush and more extensive sagebrush cover. However, there were exceptions to these trends for both groups.

Univariate patterns may have been affected by three confounding factors. First, the relatively small number of sites sampled may have masked real, but possibly weak, relationships of some bird species with the measured proximate vegetation and landcover variables. Second, point counts were conducted about evenly in two discrete time periods (mid-June and early July) during which vegetation structure (especially grass) continued to change significantly in response to wet and warm conditions; some bird species may have abandoned sites before they could be sampled, because grass density and height (especially of exotic annuals) crossed a tolerance threshold. Third, the study area was so large that some vegetation conditions favorable to particular bird species were encountered only during one of the two sample periods, and this biased the temporal results of the counts and habitat measurements. Nevertheless, significant patterns between each bird species and one or more appropriate habitat variables were identified in the univariate analysis.

Despite data caveats of small sample size for some species and a relatively extended sampling season, results suggest that any management of grassland bird species will benefit from both landscape and site considerations. GAP-derived variables, especially at the 5,000 m scale, were important and often proved to be stronger predictors of breeding bird habitat choice than vegetation variables we directly measured at the site. Managers concerned with these declining grassland bird species may wish to apply species-appropriate site vegetation management with knowledge of landscape characteristics and current GAP land cover maps. With

additional bird sampling data we will be able to apply our analysis techniques with available GIS data to model priority landscapes for specific birds that will enable focused conservation and habitat management. However, it is already known that maintaining the suite of grassland and shrubland bird species currently present requires maintaining a mosaic of grass and shrub habitat patches of various structures and patch sizes. Grazing and fire are two tools that, when used judiciously and based on the needs of each species, can help achieve this goal, but no net loss of grassland and shrubland habitat should be the underlying principle guiding land management in the region.


## Acknowledgements

We especially thank Nora Taylor of the BLM for her generous support in making this project possible. We also extend a big thanks to Eric Atkinson (Marmot's Edge Conservation) for conducting the June point counts. Tom Schemm did a great job developing GIS landscape variables, making the study area map, and providing other GIS support. Coburn Currier was essential in providing support in formatting and printing the report.

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# INTRODUCTION

Grassland and shrub-steppe bird populations have experienced more substantial declines during the last century than in any other groups of birds throughout North America (Paige and Ritter 1999, Peterjohn and Sauer 1999, Vickery et al. 1999, Knick and Rotenberry 2002). Loss of habitat for breeding and non-breeding activities, through conversion of native prairie landscapes to agricultural use, is probably the greatest contributing factor to these declines. However, grassland and shrub-steppe bird species may also be negatively impacted by other factors, such as altered patterns of fire and grazing (Kantrud and Kologiski 1982, Saab et al. 1995, Madden et al. 1999, Paige and Ritter 1999), and the introduction of non-native forage grasses (Sutter and Brigham 1998). There is also mounting evidence that climate change could result in large reductions and spatial movements of remaining native prairie habitats (Peterson 2003). Thus, the integrity of prairie landscapes is widely compromised, and conservation of prairie birds is a high priority for conservation organizations and land management agencies.

Several North American grassland and shrub-steppe birds are identified as species of concern. The 2007 National Audubon Society Watch List (Butcher et al. 2007) includes Mountain Plover (*Charadrius montanus*) and Baird's Sparrow (*Ammodramus bairdii*) on their Red Watch List, species of highest national concern because they are globally threatened. Swainson's Hawk (*Buteo swainsoni*), Greater Sage-Grouse (*Centrocercus urophasianus*), Long-billed Curlew (*Numenius americanus*), Marbled Godwit (*Limosa fedoa*), Sprague's Pipit (*Anthus spragueii*), Brewer's Sparrow (*Spizella breweri*), Sage Sparrow (*Amphispiza belli*), Lark Bunting (*Calamospiza melanocorys*), and Chestnut-collared Longspur (*Calcarius ornatus*) are on the Yellow Watch List because they are declining or rare species that could be added to the Red Watch List should their declines continue long enough to fall below certain thresholds (declining species) or should they begin or continue to decline in population (rare species). Each of the species mentioned above occurs in Montana, and most are included on the Montana Species of Concern list (Montana Natural Heritage Program and Montana Fish, Wildlife and Parks 2006).

Identifying the habitat requirements of grassland and shrub-steppe birds is an important component in the design and implementation of measures for long-term conservation of these species. Habitat selection by prairie bird species may occur at more than one spatial scale. For example, Baird's Sparrow selects taller and denser grassland vegetation in which to nest (Sutter and Brigham 1998, Dieni and Jones 2003), but occurs more often in pasture and hay fields than cropland (Davis et al. 1999) and in larger grassland habitat patches (Johnson and Igl 2001). There is evidence, however, that some grassland species may not exhibit scale-dependent responses uniformly across their ranges (Johnson and Igl 2001, Bakker et al. 2002). By identifying the scales at which birds respond most strongly to habitat and landscape features, managers will be in a position to develop effective measures to mitigate deleterious effects of habitat alteration (Cunningham and Johnson 2006).

Southeastern Montana is an area experiencing a number of habitat threats to native prairie bird populations, as is the case throughout the northern Great Plains (Knopf 1994, Askins et al. 2007). These threats include conversion of native grasslands to agricultural use, removal of shrublands to enhance livestock grazing, fire suppression and invasion of woody vegetation, invasion of exotic grasses that ultimately influence fire regimes, and rapid fragmentation of native grasslands and shrublands for urban or industrial development, especially as they relate to energy development (e.g. Walker et al. 2007). This region also supports a large diversity of grassland and shrubland bird species (Lenard et al. 2003), several of which are of conservation concern in Montana and elsewhere. Because of these considerations, we developed a study to address the following objectives 1) establish a series of point count locations to fill in bird distribution gaps and for longer-term monitoring of grassland and shrub-steppe birds, 2) explore proximate (site scale) habitat features (vegetation structure and

land cover) that relate to the presence of different grassland and shrub-steppe bird species, and 3) explore larger landscape features at several scales that may be useful in predicting the occurrence of these bird species.

# Methods

## *Study Area*

The study area includes portions of seven southeastern Montana counties: Big Horn, Carter, Custer, Fallon, Powder River, Prairie, and Rosebud. This area is part of the Great Plains with cold winters, warm summers, and considerable diurnal temperature fluctuations. The Broadus weather station is within our study area and reflects typical conditions. The average Broadus high temperature in July is 87.4º F with an average minimum in January of 6.6º F (WRCC 2007), the warmest and coldest months, respectively. Annual precipitation averages 13.56 in, and the total annual average snowfall is 40.3 in. The wettest months are June (2.4 in), May (2.3 in), April (1.5 in), and July (1.5 in); over half of the total annual precipitation falls in these four months.

The study area is within the Powder River Basin Ecological Section with Cretaceous and Lower Tertiary non-marine sedimentary rocks (McNab and Avers 1994). Elevations of the sampling locations ranged from 2,100 to 5,050 ft. The topography in lower elevations is predominately rolling but with steep erosion caused gullies and occasional rugged rock outcrops. Higher elevations have greater precipitation and support scattered forests of ponderosa pine (*Pinus ponderosa*) and rocky mountain juniper (*Juniperus scopulorum*) mixed with badland vegetation on steep eroded slopes and grasslands or sage-steppe on drier aspects. Lower elevations are a mix of native prairie grassland and sage-steppe with dry land grain farming on private land with suitable soils. Irrigated agriculture is common within and near the riparian areas of larger rivers. The most common land use is livestock grazing. Population density is low.

Soils are mostly medium to fine textured and range from shallow to deep (McNab and Avers 1994). The native prairie grassland and shrub-steppe vegetation composition of our sampling sites is primarily related to soil textural attributes (Kudray and Cooper 2005). Dominant grassland graminoid species include western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), Sandberg's bluegrass (*Poa secunda*), prairie junegrass (*Koeleria macrantha*), green needlegrass (*Nassella viridula*), bluebunch wheatgrass (*Pseudoroegneria spicata*), needle-and-thread (*Hesperostipa comata*), and sun sedge (*Carex inops* ssp. *Heliophila)* (Cooper et al. 2007). Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) is the dominant shrub with silver sagebrush (*Artemisia cana*) common on drainage terraces and sandy substrates (Cooper et al. 2007). Riparian areas support a variety of shrub and tree species.

## *Bird Point Counts*

We chose points for sampling birds based on accessibility (public lands with at least secondary road access), relative homogeneity of sagebrush or grass cover, and the general absence of trees, water bodies, roads, fences and power lines within points. Initial point selection was made during drive-by inspections. In some cases, initial points were in unsatisfactory locations, and were moved during the actual point-count sessions. Points were classified *a priori* according to the quantity of sagebrush cover (light, medium, dense, or mostly grass). We sampled birds at 116 plots (Figure 1), roughly divided equally into grass or sage points.

Our sample sites were 100 m fixed-radius point-count circles (Hutto et al. 1986, Ralph et al 1993, Davis et al. 1999, McMaster and Davis 2001). We positioned point counts at least 500 m apart, but usually a much greater distance separated them. All counts were 10 min in duration, and conducted within approximately 5 hrs following sunrise, starting no earlier than 05:30 MDT. A single observer recorded all birds that were detected visually and/or aurally within a visually estimated 100 m distance. Birds that flew over the circle but did not land during the count were recorded as flyovers. Counts were not made during continuous

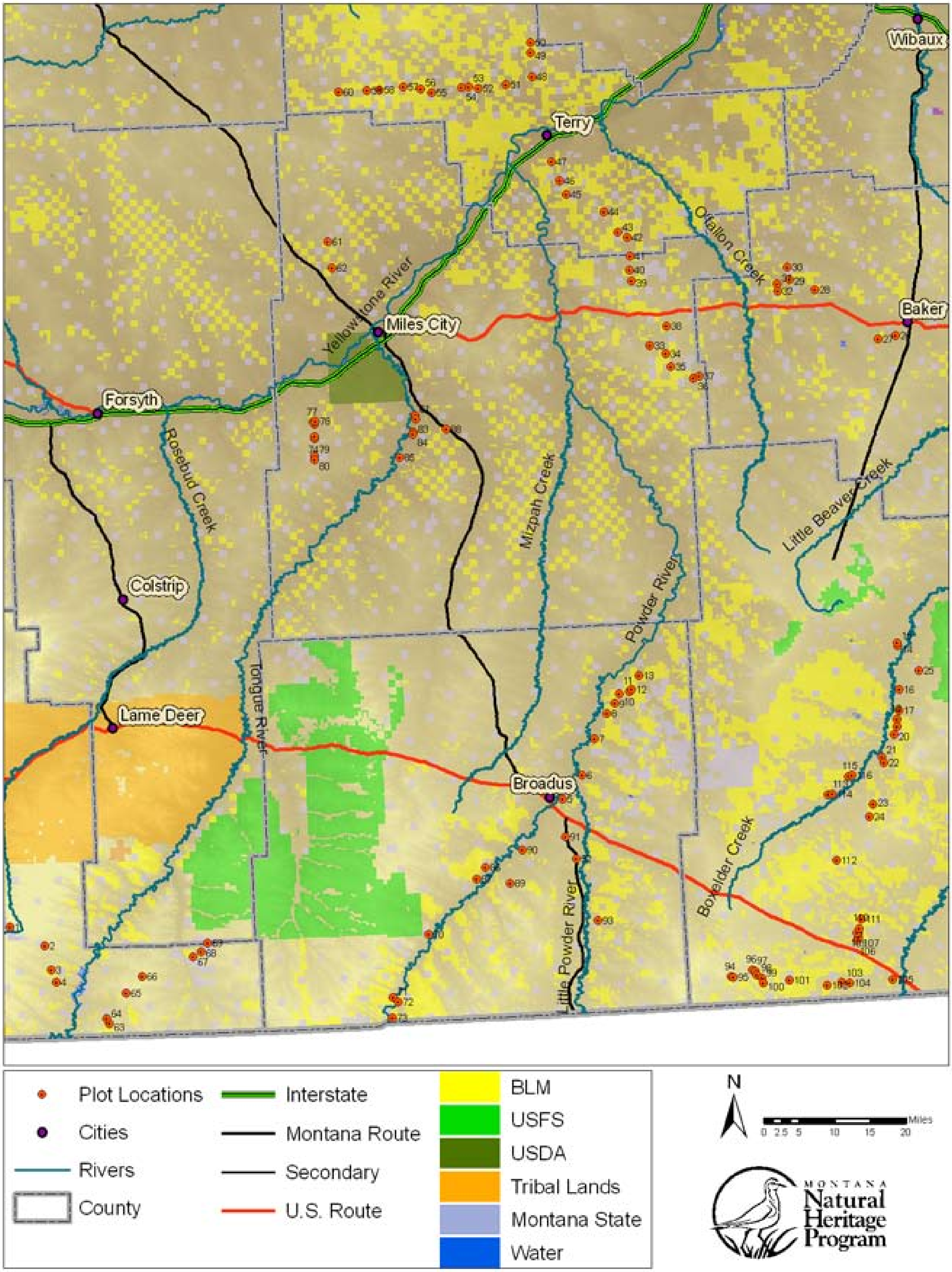


*Figure 1. Map of the Study Area.*

rain or winds generally exceeding about 20 km/hr. For logistical reasons, counts were conducted in 2007 by three observers during two discreet sampling periods: 15-23 June (62 counts) and 6-12 July (54 counts). Each point was sampled a single time.

## *Local Vegetation Measurements*

We gathered a variety of measurements that described general vegetation structure associated with each bird point-count circle. Indices for the entire count circle placed vegetation cover types (grass, bare, shrub, water, wet meadow) into cover categories (absent, trace, 1-5%, 5-10%, and multiples of 10%).

We also recorded vegetation features at five 2 m diameter mini-plots within each point-count circle. One mini-plot was located over the center of the point-count circle, the remaining four were located one each within each quarter of the point-count circle at a distance determined through use of a random numbers table, but no closer than 10 m from the center of the point count.

At each mini-plot we measured vertical vegetation density by counting the number of vegetation contacts at < 1 dm, 1-2 dm, and > 2 dm height categories on a 7 mm diameter rod held vertically. Vegetation density measurements were taken at four cardinal directions 1 m from the center of the mini-plot. We also recorded the maximum height (cm) of the vegetation of each mini-plot, the average height (cm) of standing dead vegetation (bent or flattened dead vegetation, not the sparse vertical standing stalks), and the percent ground cover (absent, trace, 1-5%, 5-10%, and each 10% category thereafter) of bare, moss, shrub, grass, and forb.

We measured percent shrub cover along four 25 m transects, one in each quarter of the point-count circle and starting at the center point of each mini-plot; transects were oriented along a randomly chosen direction. Percent shrub cover along these transects was the total length of a survey tape (dm) that intersected discrete shrub patches; we also recorded the maximum height (dm) of each intersected shrub patch.

## *Landscape and Statistical Analyses*

We derived landscape variables from a variety of GIS data sources including new USGS GAP land cover data (draft version from the USGS National Gap Analysis Program). Data sources are listed in Table 1. Similar variables were developed for each of three overlapping 200 m, 800 m, and 5,000 m circles around the bird sampling point. Variables were deleted if they occurred in < 10% of the plots.

Logistic regression is a relatively robust statistical method that does not assume a linear relationship between dependent and independent variables or require normally distributed variables. However, it does require that observations be independent and samples that are closer in space are likely to be more similar than those further apart. Spatial autocorrelation is a common issue in ecological studies and species-environment exploration studies with logistic regression can still be informative even if samples are not fully independent.

Some of the variables were highly correlated and multicollinearity was an analysis concern. Multicollinearity occurs when one or more variables are exact or near exact linear functions of other variables in the data set (Munoz and Felicisimo 2004). However, in a comparison of statistical methods used in predictive modeling, Munoz and Felicisimo (2004) found that eliminating highly correlated variables in multiple logistic regression always reduced predictive power. Therefore, we ran logistic regression models with both a full data set and a data set that had been reduced by deleting one of a pair of variables that had a correlation over 0.70 (Weisberg 1985). The original data set of >100 landscape variables and 10 site variables was reduced to 53 and 6 variables, respectively. Models were assessed with McFadden's rho-squared, a transformation of the likelihood-ratio statistic intended to mimic an *R*-squared (Steinberg and Colla 2004). It ranges from 0 to 1 and a higher value corresponds to more significant results; however rho-squared values tend to be much lower than *R*-squared (Steinberg and Colla 2004). A preliminary logistic regression

*Table 1. Original GIS variable codes and definitions. Some variables were deleted for some of the data analysis. All MT Natural Resource Information Service data is available at http://www.nris.mt.gov/. Any further derivation of GIS variables was completed with ArcGIS 9.2 software. Access dates are in parenthesis.*

| Variable Code | Definition |
|---|---|
| Energy_AR | Area of energy leases active and inactive. BLM ArcIMS map service listing of authorized oil and gas leases. (October 2007) |
| Energy_CNT | Number of energy leases active and inactive. Derived from BLM ArcIMS download. |
| swamp_AR | Area of wetlands from the 24k High Resolution National Hydrography Dataset. Montana Natural Resources Information Services. (August 2007) |
| swamp_CNT | Number of wetlands from 24k High Resolution National Hydrography Dataset |
| pond_AR | Area of standing water bodies from the 24k High Resolution National Hydrography Dataset, Montana Natural Resources Information Services. (August 2007) |
| pond_CNT | Number of standing water bodies from the 24k High Resolution National Hydrography Dataset |
| River | Length of rivers, calculated from the 24k High Resolution National Hydrography Dataset, Montana Natural Resources Information Services. (August 2007) |
| Per_streams | Length of perennial streams, calculated from the 24k High Resolution National Hydrography Dataset, Montana Natural Resources Information Services. (August 2007) |
| Eph_streams | Length of ephemeral streams from the 24k High Resolution National Hydrography Dataset, Montana Natural Resources Information Services. (August 2007) |
| Highway | Length of Highway/Interstate from the Tiger 2000 Roads layer, Montana Natural Resources Information Services. (August 2007) |
| SmallRoads | Length of all non highway roads from the Tiger 2000 Roads layer, Montana Natural Resources Information Services. (August 2007) |
| DENSIT_AWM | Human Population Density from the 2000 US Census, Montana Natural Resources Information Services. (October 2007) |
| PrivLd_AR | Area of private land from the Montana Public Land Ownership Layer, Montana Natural Resources Information Services. (October 2007) |
| PrivLd_CNT | Number of geographically separate private land parcels |
| pubLd_AR | Area of public land from the Montana Public Land Ownership Layer, Montana Natural Resources Information Services. (October 2007) |
| pubLd_CNT | Number of geographically separate parcels |
| RANGE_AWM | Montana Average Annual Precipitation, 1971-2000, Montana Natural Resources Information Services. (October 2007) |
| TINPOL_CNT | Number of TIN pieces within each buffer: a measure of topographic roughness. Derived with a 10m vertical tolerance from the 10m National Elevation Dataset. (October 2007) |
| BARREN_AR* | Area of parcels of land GAP assigned as barren |
| BARREN_CNT* | Number of geographically separate parcels of land GAP assigned as barren |
| GRASS_AR* | Area of parcels of land GAP assigned as grassland |
| GRASS_CNT* | Number of geographically separate parcels of land GAP assigned as grassland |
| H_Alt_AR* | Area of land GAP assigned as human altered built up |
| H_Alt_CNT* | Number of geographically separate parcels of land GAP assigned as human altered built up |
| H_Open_AR* | Area of land GAP assigned as human altered open |
| H_Open_CNT* | Number of geographically separate parcels of land GAP assigned as human altered open |

*Table 1. Continued.*

| Variable Code | Definition |
|---|---|
| SHRUBS_AR* | Area of land GAP assigned as shrub dominated land |
| SHRUBS_CNT* | Number of geographically separate parcels of land GAP assigned as shrub dominated land |
| TREES_CNT* | Number of geographically separate parcels of land GAP assigned as tree dominated land |
| WATER_AR* | Area of land GAP assigned as water |
| WATER_CNT* | Number of geographically separate parcels of land GAP assigned as water |

*GAP Ecological System Classification assignments. See www.natureserve.org for more information about Ecological Systems
**Barren** - Rocky Mountain Alpine Bedrock and Scree, Western Great Plains Badlands, Western Great Plains Cliff and Outcrop
**Grass** - Introduced Riparian Vegetation, Introduced Upland Vegetation - Annual Grassland, Introduced Upland Vegetation - Perennial Grassland and Forbland, Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland, Northwestern Great Plains Mixedgrass Prairie, Western Great Plains Sand Prairie.
**Human Altered** (H_Alt) - Developed, High Intensity, Developed, Low Intensity, Developed, Medium Intensity, Mining Operations
**Human Altered Open** (H_Open) - Agriculture, Pasture/Hay, Developed, Open Space.
**Shrub** - Inter-Mountain Basins Big Sagebrush Steppe, Inter-Mountain Basins Greasewood Flat, Inter-Mountain Basins Mat Saltbush Shrubland, Inter-Mountain Basins Montane Sagebrush Steppe, Introduced Upland Vegetation - Shrub, Northern Rocky Mountain Montane-Foothill Deciduous Shrubland, Rocky Mountain Lower Montane-Foothill Shrubland, Wyoming Basins Low Sagebrush Shrubland.
**Tree** - Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland, Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland, Northwestern Great Plains Floodplain, Northwestern Great Plains Ponderosa Pine, Northwestern Great Plains Riparian, Recently Burned Forest and Woodland, Rocky Mountain Foothill Limber Pine-Juniper Woodland, Southern Rocky Mountain Ponderosa Pine Woodland, Western Great Plains Dry Bur Oak Forest and Woodland, Western Great Plains Floodplain, Western Great Plains Riparian Woodland and Shrubland, Western Great Plains Wooded Draw and Ravine.
**Water** – Water, North American Arid West Emergent Marsh, Rocky Mountain Subalpine-Montane Fen, Western Great Plains Closed Depression Wetland, Western Great Plains Open Freshwater Depression Wetland, Western Great Plains Saline Depression Wetland.

data analysis of each SOC bird using full and reduced data sets indicated that the reduced data sets generally had higher rho-squared values, so only the reduced data set model results are reported in detail for each SOC bird, although full data sets were used in the comparison of logistic regression models using landscape scale and site variables. The complete data set was used for a comparison of landscape scales, since the removal of highly correlated variables differentially eliminated variables at certain scales and we wanted to test comparable data sets. In all logistic regression models we used an automatic stepwise procedure with variables entered and eliminated from the model based on probability values of 0.15. All data analysis was done with SYSTAT 11 (SYSTAT Software Inc. 2004) unless noted.

To examine the species-environment relationships among the group of SOC birds we ran a non-metric multidimensional scaling (NMS) ordination using PC-ORD version 4.20 software with default values (McCune and Mefford 1999). A small constant (.0001) was added to SOC presence-absence values (absence = 0, presence = 1) to avoid software problems due to the large presence of zeros in the species matrix. Ordination axes were correlated with the species and the environmental data.

We used parametric two-sample t-tests when analyzing site (point count) continuous vegetation variables for patterns associated with bird species presence, and nonparametric Wilcoxon Rank Sums tests for analyses of site land-cover variables that were expressed as percents. We used non-parametric tests for all analyses of association (two-by-two tables and proportions). All site univariate analyses were run on STATISTIX ® 8 (Analytical Software, Tallahassee, Florida).

# Results

## *Point Counts*

We detected 55 bird species on the 116 point counts taken during June and early July 2007; common and scientific names, as well as the number of point-count occurrences and number of individuals detected, are listed in descending order in Table 2. Of these, only 17 species (14.7%) were detected on more than 6% of the counts and only 11 (9.5%) on more than 10% of the counts.

*Table 2. Bird species detected in June and early July 2007 on 116 point counts in southeastern Montana. Species of Concern (SOC) are in bold.*

| Common Name | Scientific Name | No. Points Present | No. Individuals |
|---|---|---|---|
| Western Meadowlark | *Sturnella neglecta* | 112 | 270 |
| Vesper Sparrow | *Pooecetes gramineus* | 59 | 98 |
| **Grasshopper Sparrow** | *Ammodramus savannarum* | 56 | 112 |
| Horned Lark | *Eremophila alpestris* | 54 | 124 |
| **Lark Bunting** | *Calamospiza melanocorys* | 47 | 195 |
| **Brewer's Sparrow** | *Spizella breweri* | 33 | 86 |
| Mourning Dove | *Zenaida macroura* | 23 | 29 |
| Brown-headed Cowbird | *Molothrus ater* | 20 | 86 |
| **Chestnut-collared Longspur** | *Calcarius ornatus* | 15 | 37 |
| Upland Sandpiper | *Bartramia longicauda* | 13 | 26 |
| Brewer's Blackbird | *Euphagus cyanocephalus* | 12 | 21 |
| Lark Sparrow | *Chondestes grammacus* | 10 | 21 |
| Red-winged Blackbird | *Agelaius phoeniceus* | 9 | 23 |
| Western Kingbird | *Tyrannus verticalis* | 9 | 12 |
| **Baird's Sparrow** | *Ammodramus bairdii* | 8 | 14 |
| Rock Wren | *Salpinctes obsoletus* | 8 | 8 |
| **Sprague's Pipit** | *Anthus spragueii* | 8 | 13 |
| Killdeer | *Charadrius vociferus* | 5 | 6 |
| Northern Flicker | *Colaptes auratus* | 5 | 6 |
| American Goldfinch | *Carduelis tristis* | 4 | 6 |
| American Kestrel | *Falco sparverius* | 4 | 6 |
| Black-billed Magpie | *Pica hudsonia* | 4 | 4 |
| American Robin | *Turdus migratorius* | 3 | 3 |
| European Starling | *Sturnus vulgaris* | 3 | 112 |
| Great Blue Heron | *Ardea herodias* | 3 | 4 |
| House Wren | *Troglodytes aedon* | 3 | 5 |
| **Loggerhead Shrike** | *Lanius ludovicianus* | 3 | 3 |
| Brown Thrasher | *Toxostoma rufum* | 2 | 2 |
| Common Nighthawk | *Chordeiles minor* | 2 | 5 |
| Field Sparrow | *Spizella pusilla* | 2 | 2 |
| Mallard | *Anas platyrhynchos* | 2 | 2 |
| Savannah Sparrow | *Passerculus sandwichensis* | 2 | 2 |
| Say's Phoebe | *Sayornis saya* | 2 | 2 |
| Barn Swallow | *Hirundo rustica* | 1 | 1 |
| **Black-crowned Night-heron** | *Nycticorax nycticorax* | 1 | 1 |
| Black-headed Grosbeak | *Pheucticus melanocephalus* | 1 | 1 |
| Blue-winged Teal | *Anas discors* | 1 | 1 |
| **Bobolink** | *Dolichonyx oryzivorus* | 1 | 1 |
| Bullock's Oriole | *Icterus bullockii* | 1 | 1 |
| Cliff Swallow | *Petrochelidon fulva* | 1 | 9 |

*Table 2. Continued.*

| Common Name | Scientific Name | No. Points Present | No. Individuals |
|---|---|---|---|
| Common Grackle | *Quiscalus quiscula* | 1 | 2 |
| Downy Woodpecker | *Picoides pubescens* | 1 | 1 |
| Eastern Kingbird | *Tyrannus tyrannus* | 1 | 1 |
| **Ferruginous Hawk** | *Buteo regalis* | 1 | 1 |
| **Long-billed Curlew** | *Numenius americanus* | 1 | 1 |
| Mountain Bluebird | *Sialia currucoides* | 1 | 2 |
| Northern Harrier | *Circus cyaneus* | 1 | 2 |
| **Sage Thrasher** | *Oreoscoptes montanus* | 1 | 2 |
| Sharp-tailed Grouse | *Tympanuchus phasianellus* | 1 | 2 |
| Short-eared Owl | *Asio flammeus* | 1 | 1 |
| Turkey Vulture | *Cathartes aura* | 1 | 1 |
| Western Wood-pewee | *Contopus sordidulus* | 1 | 1 |
| Wilson's Phalarope | *Phalaropus tricolor* | 1 | 1 |
| Wilson's Snipe | *Gallinago delicata* | 1 | 1 |
| Yellow-headed Blackbird | *Xanthocephalus xanthocephalus* | 1 | 1 |

Among the 17 most frequently occurring species were five whose habitat requirements include the presence of features other than pure grassland or shrub-steppe, such as trees, rock outcrops, or wetlands; we do not address these species in our analyses. These five species (ordered by descending frequency of occurrence (Table 2) are Mourning Dove, Brewer's Blackbird, Red-winged Blackbird, Western Kingbird, and Rock Wren. A sixth species, Western Meadowlark, is also not included in any of our analyses because it was too widespread (detected on 96.7% of all counts) for us to reach any useful conclusions about its habitat requirements.

Our analyses focus on the remaining 11 species (Table 2), which were detected on 6.9-50.7% of our point counts. The multivariate analyses used only the six Montana SOC birds (Baird's Sparrow, Brewer's Sparrow, Chestnut-collared Longspur, Grasshopper Sparrow, Lark Bunting, Sprague's Pipit), whereas the univariate site analyses examine the full list of 11 species. The 11 species, and their respective frequencies of occurrence, are Vesper Sparrow (59 counts), Grasshopper Sparrow (56 counts), Horned Lark (54 counts), Lark Bunting (47 counts), Brewer's Sparrow (34 counts), Brown-headed Cowbird (21 counts), Chestnut-collared Longspur (15 counts), Upland Sandpiper (13 counts), Lark Sparrow (10 counts), Baird's Sparrow (8 counts), and Sprague's Pipit (8 counts).

## *Multi-scale Analyses for SOC Birds*

Conclusions from all results are limited by the relatively small sample size of occurrences for the six SOC birds (Table 2) and a sampling season that was relatively extended. Two variable sets were used for SOC bird logistic regression models: 1) a complete data set with only variables that occurred in <10% of the plots eliminated, and 2) a data set also reduced by eliminated one of a pair of highly correlated variables (r > 0.7). Although we incorporated some energy development variables, they represented sparse data that was additionally problematic, in that we were unable to differentiate active from future leases in the data set. The relationship of breeding bird presence/absence with landscape variables at various scales and site variables is species-specific (Table 3, Figure 2). For the six SOC birds the landscape model with the highest rho-squared value varied across landscape scales, although these values were lower than site-model rho-squared values for all but Baird's Sparrow and Sprague's Pipit. For these two species, the 5,000 m model had the highest site or landscape rho-squared value.

*Table 3. McFadden's rho-squared values for grassland bird Species of Concern log regression models using total variable sets from different landscapes scales (expressed in meters of radius) and site variables. The models are based on an automatic stepwise procedure with variables entered into or removed from the model based on probability values (p < 0.015 to enter, p > 0.015 to remove). No variables met this requirement in the 800 m data set model for Lark Bunting and Brewer's Sparrow.*

| Species/Scale | 200 | 800 | 5000 | Site |
|---|---|---|---|---|
| Grasshopper Sparrow | 0.081 | 0.151 | 0.098 | 0.215 |
| Lark Bunting | 0.289 | - | 0.285 | 0.354 |
| Brewer's Sparrow | 0.07 | - | 0.053 | 0.463 |
| Chestnut-collared Longspur | 0.039 | 0.09 | 0.056 | 0.185 |
| Baird's Sparrow | 0.198 | 0.109 | 0.327 | 0.203 |
| Sprague's Pipit | 0.147 | 0.16 | 0.723 | 0.226 |

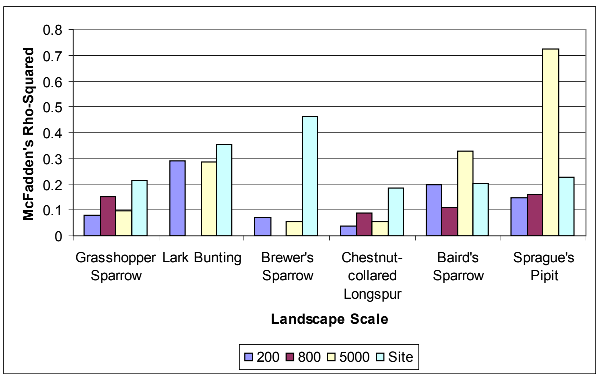


*Figure 2. Graphical representation of Table 3 ( table directly above).*

Since logistic regression McFadden's rho-squared values were higher with the reduced data set for the majority of SOC birds, we used that data set to report full model results (Table 4). GIS variable codes and definitions are listed in Table 1. All of the species models included landscape and site variables. Rho-squared values ranged from 0.391 for Grasshopper Sparrow to 0.708 for Sprague's Pipit. Rho-squared values between 0.20 and 0.40 are considered satisfactory, with higher values indicating more significant results (Hensher and Johnson 1981).

*Table 4. Log regression models for grassland bird Species of Concern. The models are based on a automatic stepwise procedure with variables entered into or removed from the model based on probability values (p < 0.015 to enter, p > 0.015 to remove).*

| **Grasshopper Sparrow** | | | | | |
|---|---|---|---|---|---|
| Log Likelihood: | -48.934 | | | | |
| | **Parameter** | **Estimate** | **S.E.** | **t-ratio** | **p-value** |
| 1 | CONSTANT | 15.927 | 4.783 | 3.33 | 0.001 |
| 2 | SAGECANOPYPE | -0.129 | 0.038 | -3.35 | 0.001 |
| 3 | MEANGRASS | -0.067 | 0.015 | -4.426 | 0 |
| 4 | MACRO_BARE | -0.139 | 0.049 | -2.839 | 0.005 |
| 5 | V8WATER_CNT | 0.843 | 0.372 | 2.268 | 0.023 |
| 6 | V2HOPENAR | 0 | 0 | 1.82 | 0.069 |
| 7 | V5PRECIP | -0.807 | 0.311 | -2.596 | 0.009 |
| | | | 95.0 % bounds | | |
| | **Parameter** | **Odds Ratio** | **Upper** | **Lower** | |
| 2 | SAGECANOPYPE | 0.879 | 0.948 | 0.815 | |
| 3 | MEANGRASS | 0.935 | 0.964 | 0.908 | |
| 4 | MACRO_BARE | 0.87 | 0.958 | 0.79 | |
| 5 | V8WATER_CNT | 2.324 | 4.817 | 1.121 | |
| 6 | V2HOPENAR | 1 | 1 | 1 | |
| 7 | V5PRECIP | 0.446 | 0.821 | 0.243 | |
| | Log Likelihood of constants only model = LL(0) = -80.336 | | | | |
| | 2*[LL(N)-LL(0)] = 62.804 with 6 df Chi-sq p-value = 0.000 | | | | |
| | McFadden's Rho-Squared = 0.391 | | | | |
| **Lark Bunting** | | | | | |
| Log Likelihood: | -42.087 | | | | |
| | **Parameter** | **Estimate** | **S.E.** | **t-ratio** | **p-value** |
| 1 | CONSTANT | -13.418 | 4.881 | -2.749 | 0.006 |
| 2 | MEANGRASS | -0.067 | 0.017 | -4.039 | 0 |
| 3 | V8GRASS_AR | 0 | 0 | 3.55 | 0 |
| 4 | V5PRECIP | 0.946 | 0.311 | 3.045 | 0.002 |
| 5 | V5H_ALT_AR | 0 | 0 | -1.367 | 0.172 |
| | | | 95.0 % bounds | | |
| | **Parameter** | **Odds Ratio** | **Upper** | **Lower** | |
| 2 | MEANGRASS | 0.935 | 0.966 | 0.905 | |
| 3 | V8GRASS_AR | 1 | 1 | 1 | |
| 4 | V5PRECIP | 2.575 | 4.732 | 1.401 | |
| 5 | V5H_ALT_AR | 1 | 1 | 1 | |
| | Log Likelihood of constants only model = LL(0) = -78.306 | | | | |
| | 2*[LL(N)-LL(0)] = 72.438 with 4 df Chi-sq p-value = 0.000 | | | | |
| | McFadden's Rho-Squared = 0.463 | | | | |

*Table 4. Continued.*

**Brewer's Sparrow**

Log Likelihood: -28.932

| | Parameter | Estimate | S.E. | t-ratio | p-value |
|---|---|---|---|---|---|
| 1 | CONSTANT | 2.913 | 1.666 | 1.749 | 0.08 |
| 2 | SAGECANOPYPE | 0.131 | 0.047 | 2.805 | 0.005 |
| 3 | MEANGRASS | -0.114 | 0.031 | -3.668 | 0 |
| 4 | AVE_MAXSAGEC | 1.215 | 0.37 | 3.285 | 0.001 |
| 5 | V2POP_DENS | 0.818 | 0.393 | 2.084 | 0.037 |
| 6 | V8PRIVLDCNT | -2.819 | 0.925 | -3.047 | 0.002 |
| 7 | V2TINPOLCNT | 0.179 | 0.059 | 3.021 | 0.003 |
| 8 | V5GRASS_CNT | -0.002 | 0.001 | -2.709 | 0.007 |
| 9 | V2HIGHWAY | 0.112 | 0.777 | 0.144 | 0.886 |

| | | | 95.0 % bounds | |
|---|---|---|---|---|
| | **Parameter** | **Odds Ratio** | **Upper** | **Lower** |
| 2 | SAGECANOPYPE | 1.14 | 1.25 | 1.04 |
| 3 | MEANGRASS | 0.892 | 0.948 | 0.839 |
| 4 | AVE_MAXSAGEC | 3.371 | 6.959 | 1.633 |
| 5 | V2POP_DENS | 2.266 | 4.892 | 1.05 |
| 6 | V8PRIVLDCNT | 0.06 | 0.366 | 0.01 |
| 7 | V2TINPOLCNT | 1.195 | 1.342 | 1.065 |
| 8 | V5GRASS_CNT | 0.998 | 0.999 | 0.997 |
| 9 | V2HIGHWAY | 1.118 | 5.122 | 0.244 |

Log Likelihood of constants only model = LL(0) = -70.169

2*[LL(N)-LL(0)] = 82.474 with 8 df Chi-sq p-value = 0.000

McFadden's Rho-Squared = 0.588

**Chestnut-collared Longspur**

Log Likelihood: -23.288

| | Parameter | Estimate | S.E. | t-ratio | p-value |
|---|---|---|---|---|---|
| 1 | CONSTANT | 0.81 | 1.037 | 0.782 | 0.435 |
| 2 | AVE_MAXSAGEC | -0.981 | 0.298 | -3.294 | 0.001 |
| 3 | V8WATER_CNT | 1.52 | 0.514 | 2.956 | 0.003 |
| 4 | V5RIVER | -0.001 | 0 | -1.951 | 0.051 |
| 5 | V5SHRUBSCNT | -0.002 | 0.001 | -3.006 | 0.003 |
| 6 | V5H_ALT_CNT | 0.038 | 0.015 | 2.586 | 0.01 |
| 7 | V2TINPOLCNT | 0.077 | 0.048 | 1.604 | 0.109 |
| 8 | V8POND_CNT | -1.375 | 0.672 | -2.046 | 0.041 |
| 9 | V2TREES_AR | 0 | 0 | 1.564 | 0.118 |

| | | | 95.0 % bounds | |
|---|---|---|---|---|
| | Parameter | Odds Ratio | Upper | Lower |
| 2 | AVE_MAXSAGEC | 0.375 | 0.672 | 0.209 |
| 3 | V8WATER_CNT | 4.573 | 12.53 | 1.669 |
| 4 | V5RIVER | 0.999 | 1 | 0.999 |
| 5 | V5SHRUBSCNT | 0.998 | 0.999 | 0.997 |
| 6 | V5H_ALT_CNT | 1.039 | 1.069 | 1.009 |
| 7 | V2TINPOLCNT | 1.08 | 1.186 | 0.983 |
| 8 | V8POND_CNT | 0.253 | 0.944 | 0.068 |
| 9 | V2TREES_AR | 1 | 1 | 1 |

Log Likelihood of constants only model = LL(0) = -44.669

2*[LL(N)-LL(0)] = 42.760 with 8 df Chi-sq p-value = 0.000

McFadden's Rho-Squared = 0.479

**Baird's Sparrow**

Log Likelihood: -12.764

| | Parameter | Estimate | S.E. | t-ratio | p-value |
|---|---|---|---|---|---|
| 1 | CONSTANT | -0.358 | 2.613 | -0.137 | 0.891 |
| 2 | V8TINPOLCNT | 0.034 | 0.011 | 2.948 | 0.003 |
| 3 | MEANMAXHEIGH | -0.248 | 0.094 | -2.645 | 0.008 |
| 4 | V5H_ALT_CNT | 0.044 | 0.02 | 2.179 | 0.029 |
| 5 | V2TREES_AR | -0.001 | 0 | -2.242 | 0.025 |
| 6 | V5PUBLDAR | 0 | 0 | 2.002 | 0.045 |
| 7 | V8POND_AR | 0 | 0 | 1.382 | 0.167 |

| | | | 95.0 % bounds | |
|---|---|---|---|---|
| | **Parameter** | **Odds Ratio** | **Upper** | **Lower** |
| 2 | V8TINPOLCNT | 1.034 | 1.058 | 1.011 |
| 3 | MEANMAXHEIGH | 0.78 | 0.938 | 0.649 |
| 4 | V5H_ALT_CNT | 1.045 | 1.087 | 1.004 |
| 5 | V2TREES_AR | 0.999 | 1 | 0.999 |
| 6 | V5PUBLDAR | 1 | 1 | 1 |
| 7 | V8POND_AR | 1 | 1.001 | 1 |

Log Likelihood of constants only model = LL(0) = -29.111

2*[LL(N)-LL(0)] = 32.694 with 6 df Chi-sq p-value = 0.000

McFadden's Rho-Squared = 0.562

**Sprague's Pipit**

Log Likelihood: -8.493

| | Parameter | Estimate | S.E. | t-ratio | p-value |
|---|---|---|---|---|---|
| 1 | CONSTANT | -30.141 | 13.794 | -2.185 | 0.029 |
| 2 | V5GRASS_CNT | 0.011 | 0.005 | 2.179 | 0.029 |
| 3 | V5H_ALT_CNT | 0.158 | 0.073 | 2.154 | 0.031 |
| 4 | V5ENERGYAR | 0 | 0 | 2.054 | 0.04 |
| 5 | CONTACTS_0_1 | -0.715 | 0.42 | -1.702 | 0.089 |
| 6 | V2BARRENCNT | 1.607 | 0.878 | 1.83 | 0.067 |
| 7 | V8H_ALT_AR | 0 | 0 | -1.582 | 0.114 |

| | | | 95.0 % bounds | |
|---|---|---|---|---|
| | **Parameter** | **Odds Ratio** | **Upper** | **Lower** |
| 2 | V5GRASS_CNT | 1.011 | 1.02 | 1.001 |
| 3 | V5H_ALT_CNT | 1.171 | 1.352 | 1.014 |
| 4 | V5ENERGYAR | 1 | 1 | 1 |
| 5 | CONTACTS_0_1 | 0.489 | 1.114 | 0.215 |
| 6 | V2BARRENCNT | 4.987 | 27.879 | 0.892 |
| 7 | V8H_ALT_AR | 1 | 1 | 1 |

Log Likelihood of constants only model = LL(0) = -29.111

2*[LL(N)-LL(0)] = 41.235 with 6 df Chi-sq p-value = 0.000

McFadden's Rho-Squared = 0.708

Non-metric multidimensional scaling (NMS) is an ordination technique that is well suited to data that are non-normal (McCune and Medford 1999). R squared values indicate the strength of ordination axes, and higher values indicate a more significant axis (Table 5). Environmental variables and species are correlated with axes (Table 6 and Table 7, respectively). Higher r absolute values indicate stronger correlation and the sign (positive or negative) indicates the direction of the correlation.

*Table 5. Coefficients of determination for the correlations between NMS ordination distances and distances in the original n-dimensional space.*

| | R Squared | |
|---|---|---|
| **Axis** | **Increment** | **Cumulative** |
| 1 | 0.438 | 0.438 |
| 2 | 0.152 | 0.59 |
| 3 | 0.331 | 0.92 |

*Table 6. Pearson and Kendall Correlations – environmental variables with NMS Ordination Axes. The three highest correlations for each axis are in bold.*

| | **Axis 1** | | | **Axis 2** | | | **Axis 3** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **r** | **r-sq** | **tau** | **r** | **r-sq** | **tau** | **r** | **r-sq** | **tau** |
| 5Energy_AR | 0.018 | 0 | 0.057 | -0.053 | 0.003 | -0.112 | -0.18 | 0.033 | -0.182 |
| 5pond_AR | -0.123 | 0.015 | -0.004 | 0.046 | 0.002 | 0.035 | -0.185 | 0.034 | -0.138 |
| 5pond_CNT | -0.1 | 0.01 | 0.053 | -0.009 | 0 | -0.066 | -0.373 | 0.139 | -0.301 |
| 5River | -0.137 | 0.019 | -0.215 | 0.235 | 0.055 | 0.128 | -0.01 | 0 | 0.023 |
| 5Per_streams | -0.332 | 0.11 | -0.04 | 0.024 | 0.001 | -0.023 | -0.178 | 0.032 | -0.142 |
| 5Eph_streams | 0.11 | 0.012 | 0.056 | 0.042 | 0.002 | 0.032 | -0.03 | 0.001 | -0.001 |
| 5Highway | -0.238 | 0.057 | -0.143 | 0.115 | 0.013 | 0.052 | -0.115 | 0.013 | -0.035 |
| 5SmallRoads | -0.244 | 0.06 | -0.224 | 0.154 | 0.024 | 0.061 | 0.113 | 0.013 | 0.058 |
| 5DENSIT_AWM | 0.042 | 0.002 | -0.164 | 0.098 | 0.01 | 0.047 | -0.155 | 0.024 | -0.04 |
| 5pubLd_AR | 0.16 | 0.026 | 0.099 | -0.086 | 0.007 | 0.01 | 0.049 | 0.002 | 0.03 |
| 5pubLd_CNT | 0.14 | 0.02 | 0.12 | -0.075 | 0.006 | -0.05 | 0.077 | 0.006 | 0.066 |
| 5RANGE_AWM | 0.067 | 0.004 | 0.225 | -0.096 | 0.009 | -0.135 | **-0.393** | 0.154 | -0.315 |
| 5BARREN_AR | -0.136 | 0.019 | -0.178 | 0.068 | 0.005 | 0.11 | **0.4** | 0.16 | 0.263 |
| 5GRASS_CNT | -0.116 | 0.013 | -0.137 | -0.05 | 0.003 | -0.006 | 0.262 | 0.069 | 0.2 |
| 5H_Alt_AR | -0.13 | 0.017 | -0.113 | 0.11 | 0.012 | 0.127 | -0.068 | 0.005 | 0.101 |
| 5H_Alt_CNT | 0.014 | 0 | -0.04 | 0.065 | 0.004 | 0.081 | 0.285 | 0.081 | 0.12 |
| 5H_Open_AR | -0.072 | 0.005 | -0.064 | 0.074 | 0.005 | 0.08 | -0.018 | 0 | 0.004 |
| 5H_Open_CNT | -0.061 | 0.004 | -0.023 | 0.147 | 0.022 | 0.086 | -0.115 | 0.013 | -0.099 |
| 5SHRUBS_CNT | 0.05 | 0.003 | 0.004 | 0.146 | 0.021 | 0.096 | 0.231 | 0.053 | 0.121 |
| 5TREES_CNT | -0.112 | 0.013 | -0.085 | 0.06 | 0.004 | 0.055 | -0.009 | 0 | 0.031 |
| 8pond_AR | -0.05 | 0.002 | -0.007 | -0.078 | 0.006 | -0.045 | -0.089 | 0.008 | -0.113 |
| 8pond_CNT | -0.011 | 0 | 0.032 | 0.004 | 0 | -0.009 | -0.09 | 0.008 | -0.096 |
| 8Per_streams | -0.061 | 0.004 | 0.028 | -0.237 | 0.056 | -0.083 | -0.054 | 0.003 | -0.079 |
| 8Eph_streams | -0.092 | 0.008 | -0.064 | 0.056 | 0.003 | 0.04 | -0.006 | 0 | -0.002 |
| 8Highway | **-0.365** | 0.133 | -0.269 | 0.197 | 0.039 | 0.123 | -0.108 | 0.012 | -0.042 |
| 8SmallRoads | -0.064 | 0.004 | -0.136 | 0.009 | 0 | 0.01 | 0.19 | 0.036 | 0.125 |
| 8PrivLd_CNT | 0.077 | 0.006 | -0.014 | -0.021 | 0 | 0.007 | 0.176 | 0.031 | 0.127 |
| 8pubLd_AR | -0.03 | 0.001 | 0.023 | 0.025 | 0.001 | 0.019 | -0.196 | 0.038 | -0.095 |
| 8pubLd_CNT | 0.163 | 0.026 | 0.114 | -0.007 | 0 | 0.046 | 0.079 | 0.006 | 0.074 |
| 8TINPOL_CNT | 0.01 | 0 | -0.026 | 0.03 | 0.001 | 0.004 | 0.134 | 0.018 | 0.117 |

*Table 6. Continued.*

| | Axis 1 | | | Axis 2 | | | Axis 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | **r** | **r-sq** | **tau** | **r** | **r-sq** | **tau** | **r** | **r-sq** | **tau** |
| 8BARREN_CNT | -0.159 | 0.025 | -0.182 | 0.089 | 0.008 | 0.092 | 0.059 | 0.003 | 0.021 |
| 8GRASS_AR | 0.325 | 0.106 | 0.294 | -0.165 | 0.027 | -0.087 | -0.078 | 0.006 | -0.061 |
| 8GRASS_CNT | -0.084 | 0.007 | -0.135 | -0.02 | 0 | 0.004 | 0.212 | 0.045 | 0.141 |
| 8H_Alt_AR | -0.161 | 0.026 | -0.118 | 0.122 | 0.015 | 0.085 | 0.033 | 0.001 | 0.047 |
| 8HOpen_CNT | -0.059 | 0.003 | -0.073 | 0.196 | 0.038 | 0.198 | 0.086 | 0.007 | 0.018 |
| 8TREES_AR | 0.004 | 0 | -0.016 | -0.143 | 0.021 | -0.049 | 0.008 | 0 | 0.04 |
| 8WATER_CNT | 0.201 | 0.04 | 0.192 | -0.111 | 0.012 | -0.007 | 0.089 | 0.008 | 0.061 |
| 2Energy_CNT | -0.025 | 0.001 | -0.002 | -0.062 | 0.004 | -0.047 | -0.158 | 0.025 | -0.173 |
| 2Eph_Streams | -0.111 | 0.012 | -0.1 | -0.03 | 0.001 | -0.049 | -0.032 | 0.001 | -0.023 |
| 2Highway | -0.041 | 0.002 | -0.086 | 0.179 | 0.032 | 0.09 | -0.105 | 0.011 | -0.066 |
| 2Smallroads | -0.234 | 0.055 | -0.091 | -0.022 | 0 | -0.026 | 0.068 | 0.005 | 0.051 |
| 2DENSIT_AWM | -0.05 | 0.002 | -0.018 | 0.21 | 0.044 | 0.048 | -0.036 | 0.001 | -0.086 |
| 2PrivLd_AR | 0.056 | 0.003 | -0.008 | 0.019 | 0 | 0.043 | -0.058 | 0.003 | 0.069 |
| 2PrivLd_CNT | 0.005 | 0 | -0.006 | 0.053 | 0.003 | 0.054 | 0.092 | 0.008 | 0.069 |
| 2pubLd_CNT | 0.035 | 0.001 | 0.074 | -0.053 | 0.003 | -0.052 | 0.077 | 0.006 | 0.076 |
| 2TINPOL_CNT | -0.093 | 0.009 | -0.083 | 0.087 | 0.008 | 0.046 | 0.132 | 0.017 | 0.09 |
| 2BARREN_AR | -0.038 | 0.001 | -0.087 | 0.138 | 0.019 | 0.096 | 0.001 | 0 | 0.029 |
| 2BARREN_CNT | -0.054 | 0.003 | -0.098 | 0.068 | 0.005 | 0.082 | 0.06 | 0.004 | 0.039 |
| 2GRASS_AR | 0.265 | 0.07 | 0.232 | -0.08 | 0.006 | -0.055 | -0.153 | 0.023 | -0.097 |
| 2GRASS_CNT | -0.042 | 0.002 | -0.113 | -0.037 | 0.001 | 0 | 0.139 | 0.019 | 0.083 |
| 2H_Open_AR | 0.064 | 0.004 | -0.041 | 0.07 | 0.005 | 0.138 | 0.207 | 0.043 | 0.173 |
| 2H_Open_CNT | -0.13 | 0.017 | -0.059 | 0.026 | 0.001 | 0.134 | 0.127 | 0.016 | 0.154 |
| 2TREES_AR | -0.088 | 0.008 | -0.05 | -0.076 | 0.006 | -0.07 | 0.013 | 0 | 0 |
| MeanMaxHeight | -0.151 | 0.023 | -0.098 | **0.252** | 0.064 | 0.124 | -0.186 | 0.035 | -0.157 |
| Contacts_0_1 | **-0.512** | 0.262 | -0.336 | 0.157 | 0.025 | 0.076 | -0.017 | 0 | 0.044 |
| Macro_%Bare | 0.145 | 0.021 | 0.175 | -0.149 | 0.022 | -0.073 | -0.285 | 0.082 | -0.273 |
| SageCanopyPercent | 0.168 | 0.028 | 0.198 | **0.384** | 0.148 | 0.175 | **-0.578** | 0.334 | -0.425 |
| Ave_MaxSageCanopyHeight | 0.023 | 0.001 | 0.034 | **0.383** | 0.147 | 0.254 | -0.317 | 0.101 | -0.227 |
| Mean%Grass | **-0.584** | 0.341 | -0.408 | 0.112 | 0.013 | 0.062 | 0.21 | 0.044 | 0.202 |

*Table 7. Pearson and Kendall Correlations - bird Species of Concern with NMS Ordination Axes.*

| | Axis 1 | | | Axis 2 | | | Axis 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | **r** | **r-sq** | **tau** | **r** | **r-sq** | **tau** | **r** | **r-sq** | **tau** |
| GRSP | 0.532 | 0.283 | 0.343 | -0.06 | 0.004 | 0.066 | 0.782 | 0.611 | 0.638 |
| LARB | 0.622 | 0.386 | 0.709 | -0.398 | 0.158 | -0.336 | -0.445 | 0.198 | -0.399 |
| BRSP | 0.355 | 0.126 | 0.299 | 0.61 | 0.372 | 0.463 | -0.587 | 0.344 | -0.505 |
| CCLO | 0.058 | 0.003 | -0.085 | -0.532 | 0.283 | -0.409 | 0.44 | 0.193 | 0.356 |
| BAIS | 0.112 | 0.013 | 0.035 | -0.106 | 0.011 | -0.077 | 0.353 | 0.124 | 0.279 |
| SPPI | 0.051 | 0.003 | -0.052 | -0.321 | 0.103 | -0.255 | 0.441 | 0.194 | 0.326 |

## *Bird Presence and Site Variables*

There were significant differences for each species in at least one of the seven local-site habitat variables (Table 8), comparing count circles where a species was detected with those where it wasn't. Small sample size of detection for some species, such as Baird's Sparrow and Sprague's Pipit, appeared to affect the statistical significance of some comparisons where the differences seemed large.

Presence of nine species appeared to be related to vegetation density (Table 8) expressed as the number of vegetation contacts on a vertical rod (the exceptions were Brewer's Sparrow and Upland Sandpiper); all but the Lark Sparrow were associated with less-dense vegetation. The presence of nine species appeared related to the mean maximum height of all vegetation (usually grass), mean maximum height of sagebrush, or both. All grassland species (Baird's Sparrow, Chestnut-collared Longspur, Grasshopper Sparrow, Horned Lark, Sprague's Pipit, Upland Sandpiper) occupied sites with shorter vegetation and/or sagebrush. The shrub-steppe species (Brown-headed Cowbird, Brewer's Sparrow, Lark Bunting, Lark Sparrow, Vesper Sparrow) occupied sites with slightly to substantially taller sagebrush. The pattern shown by shrub-steppe species to maximum vegetation (primarily grass) height was mixed, with three present on sites with somewhat shorter vegetation and two on sites with somewhat taller vegetation.

The presence of three species (Brewer's Sparrow, Grasshopper Sparrow, and Lark Bunting) appeared related to the amount of bare ground in the count circle (Table 8), with Brewer's Sparrow and Lark Bunting favoring more bare ground and Grasshopper Sparrow less. The amount of grass cover appeared to affect the presence of five species (Brewer's Sparrow, Horned Lark, Lark Bunting, Lark Sparrow, Vesper Sparrow), however, only Lark Sparrow occupied sites with greater grass cover than unoccupied sites. The presence of six species appeared related to the amount of sagebrush cover; Brewer's Sparrow, Lark Bunting, and Vesper Sparrow tended to be detected more often where sagebrush cover exceeded 10%, whereas Chestnut-collared Longspur, Grasshopper Sparrow, and Sprague's Pipit tended to be detected where sagebrush cover was about 5% or less. Baird's Sparrow also seemed to appear in sites with little sagebrush cover, but the relationship was not as strong ($P<0.08$) as for the other species ($P<0.03$).

## *Point Count Vegetation, Site Land Cover, and Sampling Period*

Point counts exhibited a large range of vegetation and land cover conditions in 2007 (Table 9), which was also reflected in the broad diversity of bird species we detected during the counts (Table 2). Vegetation and land cover variables were not uniform among the two discrete time periods when points were sampled. Vegetation density (measured as vegetation contacts) and overall mean vegetation height were substantially greater during the late point count sampling period, but mean sagebrush height was only slightly greater. Land cover measures (% bare ground, % grass cover, % sagebrush cover) also tended to be greater for the late point counts, but not to the degree as vegetation density and overall height, which primarily were measures of grass structure.

## *Bird Presence and Point Count Sampling Period*

The time period when sampling occurred affected the presence of six bird species on our point counts (Table 10), and appeared to be related to the primary vegetation (grassland or shrub-steppe) with which each species was associated. We detected five of six species primarily associated with grasslands more often during the early period of point counts, the exception being Upland Sandpiper. In contrast, four of five shrub-steppe species showed no substantial difference between the early and late period counts; the one species that did (Lark Sparrow) was detected only during the late count period.

*Table 8. Relationships between bird presence and site habitat-variables. Species values for each variable are means (SD). Top line is for points where species was not detected, middle line where species was present, bottom line is the P value for the comparison between points where species was detected and not detected. All comparisons where P < 0.05 are in bold. Number of points where species was detected is in parenthesis after the species acronym. Total point counts = 116.*

| Site Variable | BAIS [1] (8) | BHCO (21) | BRSP (34) | CCLO (15) | GRSP (56) | HOLA (54) | LARB (47) | LASP (11) | SPPI (8) | UPSA (13) | VESP (59) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **contacts 0-1 dm [2]** | 15.7 (9.2) | 15.8 (9.5) | 15.9 (9.2) | 15.8 (9.4) | 17.3 (9.8) | 18.8 (9.6) | 18.3 (9.2) | 14.3 (8.7) | 15.8 (9.2) | 15.3 (8.9) | 17.9 (9.6) |
| | 11.1 (3.5) | 13.7 (6.6) | 14.1 (8.6) | 12.5 (5.6) | 13.3 (7.7) | 11.4 (6.4) | 11.1 (6.8) | 25.7 (4.5) | 10.3 (3.0) | 15.9 (10.3) | 13.0 (7.8) |
| | **0.009** | 0.248 | 0.297 | 0.067 | **0.016** | **<0.000** | **<0.000** | **<0.000** | **0.001** | 0.822 | **0.004** |
| **contacts >1 dm [2]** | 19.4 (15.0) | 20.3 (15.4) | 20.3 (14.4) | 20.0 (15.2) | 20.7 (15.2) | 24.5 (16.0) | 24.7 (15.8) | 18.1 (14.7) | 19.4 (14.9) | 19.6 (14.7) | 23.6 (16.3) |
| | 15.9 (7.0) | 14.0 (8.2) | 16.2 (14.7) | 13.5 (8.0) | 17.4 (13.8) | 12.9 (9.6) | 10.9 (6.7) | 28.5 (9.2) | 16.0 (9.0) | 15.3 (13.7) | 14.8 (11.1) |
| | 0.245 | **0.011** | 0.176 | **0.018** | 0.223 | **<0.000** | **<0.000** | **0.025** | 0.532 | 0.319 | **0.001** |
| **mean max veg height (cm) [2]** | 56.3 (16.3) | 56.8 (16.8) | 53.2 (15.1) | 56.7 (16.6) | 58.2 (15.4) | 63.1 (16.5) | 57.1 (17.8) | 54.4 (16.5) | 55.9 (16.7) | 56.5 (16.3) | 57.4 (18.7) |
| | 41.8 (7.5) | 48.3 (11.6) | 60.4 (18.2) | 46.0 (10.8) | 52.1 (16.8) | 46.3 (10.4) | 52.6 (13.6) | 63.3 (11.7) | 47.0 (3.8) | 45.4 (13.4) | 53.2 (13.5) |
| | **<0.000** | **0.008** | **0.046** | **0.003** | **0.044** | **<0.000** | 0.132 | 0.087 | **<0.000** | **0.02** | 0.164 |
| **mean max sage height (dm) [2]** | 2.8 (2.2) | 2.7 (2.3) | 2.2 (2.2) | 3.0 (2.2) | 3.2 (2.3) | 3.3 (2.4) | 2.7 (2.6) | 2.6 (2.1) | 2.8 (2.2) | 2.8 (2.2) | 2.4 (2.5) |
| | 1.8 (2.1) | 3.2 (1.8) | 4.0 (1.6) | 1.1 (1.8) | 2.3 (2.1) | 2.1 (1.7) | 2.8 (1.6) | 4.2 (2.4) | 1.8 (2.2) | 2.4 (2.1) | 3.1 (1.9) |
| | 0.186 | 0.315 | **<0.000** | **0.002** | **0.035** | **0.004** | 0.945 | **0.023** | 0.186 | 0.529 | 0.099 |
| **macro % bare ground [3]** | 3.9 (8.0) | 3.7 (8.2) | 3.2 (8.1) | 3.9 (8.2) | 5.3 (9.6) | 2.7 (5.8) | 1.9 (5.0) | 4.2 (8.2) | 4.1 (8.1) | 4.0 (8.1) | 3.0 (7.1) |
| | 3.0 (7.0) | 4.5 (6.7) | 5.2 (7.2) | 3.1 (5.8) | 2.3 (5.2) | 5.1 (9.7) | 6.7 (10.2) | 0.6 (1.2) | 0.5 (1.4) | 2.5 (6.0) | 4.6 (8.5) |
| | 0.687 | 0.457 | **0.019** | 0.996 | **0.029** | 0.114 | **<0.000** | 0.171 | 0.19 | 0.425 | 0.208 |
| **mean % grass [3]** | 53.0 (25.6) | 53.7 (16.8) | 58.7 (24.3) | 54.2 (26.2) | 56.7 (29.1) | 61.6 (26.7) | 65.1 (24.1) | 50.1 (23.8) | 53.5 (25.5) | 53.1 (25.1) | 62.0 (26.4) |
| | 57.4 (12.0) | 51.8 (23.0) | 40.4 (21.6) | 47.6 (12.1) | 49.8 (19.0) | 43.8 (18.7) | 36.0 (13.1) | 84.3 (8.7) | 51.0 (15.8) | 55.3 (24.3) | 44.9 (20.3) |
| | 0.343 | 0.782 | **<0.000** | 0.636 | 0.777 | **0.001** | **<0.000** | **<0.000** | 0.978 | 0.739 | **<0.000** |
| **% sage canopy [3]** | 8.9 (9.9) | 8.6 (10.0) | 4.7 (6.9) | 9.4 (9.9) | 11.7 (11.1) | 10.4 (11.1) | 6.6 (9.9) | 8.4 (9.7) | 9.0 (9.8) | 8.5 (9.7) | 6.2 (8.6) |
| | 2.6 (3.4) | 7.9 (8.5) | 17.7 (9.4) | 2.2 (3.9) | 5.1 (6.5) | 6.7 (7.4) | 11.3 (8.7) | 9.5 (10.3) | 1.4 (2.2) | 8.1 (9.8) | 10.8 (10.2) |
| | 0.077 | 0.631 | **<0.000** | **0.001** | **0.002** | 0.259 | **0.001** | 0.573 | **0.026** | 0.884 | **0.002** |

[1] BAIS (Baird's Sparrow), BHCO (Brown-headed Cowbird), BRSP (Brewer's Sparrow), CCLO (Chestnut-collared Longspur), GRSP (Grasshopper Sparrow), HOLA (Horned Lark), LARB (Lark Bunting), LASP (Lark Sparrow), SPPI (Sprague's Pipit), UPSA (Upland Sandpiper), VESP (Vesper Sparrow)

[2] Statistical results based on Two-sample T-test, adjusted for unequal variances when necessary.

[3] Statistical results based on Wilcoxon Rank Sums test.

*Table 9. Vegetation and land cover at point counts in southeastern Montana. Early counts (n = 62) occurred during 15-23 June, late counts (n = 54) during 6-12 July 2007. Values are means (SD).*

| | Early | Late | P[1] |
|---|---|---|---|
| **contacts 0-1 dm** | 9.5 (3.4) | 22.1 (8.5) | <0.000 |
| **contacts >1 dm** | 14.7 (10.7) | 24.2 (16.7) | 0.001 |
| **mean max veg height (cm)** | 46.5 (11.6) | 65.3 (15.1) | <0.000 |
| **mean max sage height (dm)** | 2.4 (1.9) | 3.1 (2.4) | 0.127 |
| **macro % bare ground** | 3.3 (6.9) | 4.4 (8.9) | 0.877 |
| **mean % grass** | 47.8 (15.9) | 59.7 (31.2) | 0.085 |
| **% sage canopy** | 6.6 (8.3) | 10.6 (10.7) | 0.077 |

[1] Wilcoxon Rank Sums test

*Table 10. Bird presence, primary vegetation association (grassland, shrubsteppe), and the point count sampling period. Mean dates are for points where detected (not detected), ranges are the bounds for dates of detection. Numbers in parentheses following bird species acronyms are the number of point counts where the species was detected (total point counts = 116).*

| | Veg association[1] | Mean | Range | P[2] |
|---|---|---|---|---|
| **BAIS[3] (8)** | grassland | 19 Jun (29 Jun) | 16-20 Jun | 0.018 |
| **BHCO (21)** | shrubsteppe | 26 Jun (29 Jun) | 16 Jun-12 Jul | 0.308 |
| **BRSP (34)** | shrubsteppe | 30 Jun (28 Jun) | 16 Jun-11 Jul | 0.275 |
| **CCLO (15)** | grassland | 22 Jun (29 Jun) | 16 Jun-8 Jul | 0.053 |
| **GRSP (56)** | grassland | 24 Jun (2 Jul) | 15 Jun-10 Jul | 0.001 |
| **HOLA (54)** | grassland | 24 Jun (2 Jul) | 16 Jun-9 Jul | <0.000 |
| **LARB (47)** | shrubsteppe | 27 Jun (29 Jun) | 15 Jun-9 Jul | 0.601 |
| **LASP (11)** | shrubsteppe | 10 Jul (27 Jun) | 8-12 Jul | 0.001 |
| **SPPI (8)** | grassland | 19 Jun (29 Jun) | 17-20 Jun | 0.018 |
| **UPSA (13)** | grassland | 28 Jun (29 Jun) | 19 Jun-12 Jul | 0.745 |
| **VESP (59)** | shrubsteppe | 27 Jun (29 Jun) | 16 Jun-11 Jul | 0.464 |

[1] Fisher Exact Test: P = 0.080, comparing the proportion of grassland versus shrubsteppe bird species showing a significant difference (P < 0.1) in early (15-23 Jun) and late (6-12 Jul) period point-count occurrences.

[2] Chi-Square Test with Yate's Correction, comparing the proportion of early and late period point counts where species was detected.

[3] BAIS (Baird's Sparrow), BHCO (Brown-headed Cowbird), BRSP (Brewer's Sparrow), CCLO (Chestnut-collared Longspur), GRSP (Grasshopper Sparrow), HOLA (Horned Lark), LARB (Lark Bunting), LASP (Lark Sparrow), SPPI (Sprague's Pipit), UPSA (Upland Sandpiper), VESP (Vesper Sparrow)

# Discussion

## *Site (Point Count) Scale*

Our site analyses identified several patterns between vegetation structure, land cover, and the presence of grassland and shrubland birds in southeastern Montana prairies (Table 8), but unusual weather conditions during May through early July 2007 probably affected some of the patterns, as we will discuss shortly. Perhaps most surprising was a nearly unanimous response by all six grassland species for less dense and shorter vegetation. Chestnut-collared Longspur and Horned Lark are present typically in sites with short and sparse vegetation (Beason 1995, Hill and Gould 1997), but Baird's Sparrow, Grasshopper Sparrow, Sprague's Pipit, and Upland Sandpiper are usually associated with moderately dense and tall grass (Vickery 1996, Robbins and Dale 1999, Houston and Bowen 2001, Green et al. 2002).

The presence of shrubs is a general prerequisite for the occurrence of shrubland bird species throughout their ranges (Rotenberry et al. 1999, Shane 2000, Jones and Cornely 2002) and our study supports this. Shrubland bird species present in our study area, such as Brewer's Sparrow and Lark Bunting, generally were present at sites with taller and more extensive sagebrush cover. Lark Sparrow was the most extreme in its preference for sites with taller sagebrush and taller, denser, and more extensive grass cover, more so than any of the grassland species. Lark Sparrow has a general association with taller and denser grass and shrub cover, often where vegetation is 10-20 dm tall (Martin and Parrish 2000), and is less associated with sagebrush than the other shrubland sparrows considered in our study. Brown-headed Cowbird was associated with shorter and less dense grass but taller sagebrush, a pattern that fits the general understanding of their habitat needs (Shaffer et al. 2003). Grass density affects the ability of cowbirds to find hosts directly, by making host nests more obscure, or indirectly, because hosts abandoned sites due to vegetation structure exceeding tolerable thresholds. An important component of cowbird habitat is the availability of perches from which to display and sing. Thus, taller sagebrush at sites of its presence fits the expected pattern.

Southeastern Montana experienced above-average precipitation during late spring and early summer 2007, which delayed the onset of our point counts. This was followed by above-average air temperatures, which promoted the robust growth of grasses (Table 9). The density and height of exotic cheatgrass (*Bromus tectorum*) and field (formerly Japanese) brome (*B. arvensis* formerly *B. japonicus*) were particularly striking during the study, but especially so in the second sampling period (Figure 3a-d).

*Figure 3a-b. Sampled points showing grass conditions in July 2007.*


*Figure 3c-d. Sampled points showing grass conditions in July 2007.*

The change in vegetation and land-cover conditions during our study apparently affected the results of our bird point counts. Species most reliant on open grassland habitats were encountered less frequently during our second sampling period, in early July (Table 10), suggesting that most of these species (e.g., Baird's Sparrow, Chestnut-collared Longspur, Grasshopper Sparrow, Horned Lark, Sprague's Pipit) exceeded some preferred threshold in vegetation structure (density and height), and ceased with reproductive activities. For example, Baird's Sparrow is usually found where grass is < 40 cm tall (Winter 1999), Chestnut-collared Longspur where grass < 20-30 cm tall (Hill and Gould 1997), and Sprague's Pipit where grass is < 30 cm tall (Robbins and Dale 1999). The mean maximum vegetation (= grass) height at our sites was 46.5 cm during our June counts and 65.3 cm for the July counts (Table 9), in excess of grass height preferences for the three species mentioned. Horned Larks are known to abandon nesting areas by late spring in response to the growth of vegetation (Beason 1995). Under the unusual weather conditions of 2007, other grassland bird species may have employed similar tactics, as many typically continue nesting activities into early July (Dale et al. 1997, Davis 2003). The general lack of response shown by the shrubland species to differences in vegetation conditions between the two sampling periods (Table 10) supports our argument, as shrubs should respond to favorable growth conditions with less dramatic changes over a longer time span.

The size of our area of study is another factor that likely influenced our results to some degree. It is reasonable to assume that there are significant land-cover differences within the region we surveyed that would influence when and where we encountered some bird species. The percent cover difference in grass and sagebrush between June and July (Table 9) is consistent with this possibility. Thus, spatial variation in land cover could be the sole explanation why Baird's Sparrow and Sprague's Pipit were detected only during the first sampling period (Table 10) and Lark Sparrow only during the second period. We cannot entirely discount this possibility, but think the limited detection of these three species is likely a result of vegetation condition and geographical location combined, rather than either one alone. Other species with strong ties to grass or sagebrush were found throughout the sampling period, despite the evident effect that sampling period had on species detections (Table 10). This aspect of our results, nevertheless, raises questions regarding scale of study design and sampling intensity. Single-sample surveys of bird communities may result in misleading interpretations of patterns because of habitat variation at relatively small temporal and spatial scales (Wiens 1981). Multiple visits to sites would result in more complete lists of bird species associated with each site, but this limits the area of study due to the increased logistics demanded by repeated visits. Single visits to points are probably satisfactory enough for prioritizing conservation efforts (Siegel et al. 2001), through comparisons of species richness and habitat relationships at many more sites. Our study would have benefited

by conducting more point counts over the area we surveyed or concentrating the points we visited within a smaller geographical area.

## *Multi-scale Analyses for SOC Birds*

Several studies have indicated that many prairie bird species respond to habitat features at several scales, from local patches around nest sites and territories (Kantrud and Higgins 1992, Dieni and Jones 2003), to extensive habitat patches and large landscapes covering many square kilometers (Knick and Rotenberry 2000, Johnson and Igl 2001, Bakker et al. 2002, Cunningham and Johnson 2006). Our results suggest that this also applies to some prairie bird species in southeastern Montana.

The importance of both local and landscape factors is evident for all SOC birds when logistic regression rho-squared values are compared for the various data sets (Table 3 and Figure 2), and the species specific models (Table 4). Individual species varied in their response to site and landscape variables, as well as to the scale of landscape variables. Estimate values (Table 4) give a direction of the relationship between species presence and the variables. Higher grass cover within the 800 m landscape scale and 5,000 m precipitation were important variables for Lark Bunting along with lower site grass cover. Chestnut-collared Longspurs responded positively to the number of water bodies within 800 m along with a negative response to the cover of sage at the site. The most important model variable for Baird's Sparrow was topographic roughness within 800 m, while the first three variables entered into the Sprague's Pipit model were 5,000 m landscape factors. These examples need to be verified with more data, but the relative strength of landscape factors in species models may allow a better focus of management and conservation through the development of GIS predictive models based on USGS GAP land cover data and other GIS variables.

The NMS ordination also supports the importance of both local and landscape factors for SOC bird breeding habitat selection. Axis 1 explained the most variation with an $r^2$ value of 0.438 (Table 5) and primarily reflects strong site factor relationship to grass cover (Mean%Grass, r = -.512) and grass density (Contacts_0_1, r = -.584) (Table 6). Bird species that have relatively strong positive correlations to this axis, Lark Bunting and Brewer's Sparrow, are associated with lower grass cover and density at site-level scales. Axis 3 is the next most important ($r^2$ value of 0.331) and is a complex site-landscape axis with strong negative correlations to average sage canopy (SageCanopyPercent, r = -0.578) and large scale precipitation (5RANGE_AWM, r = -0.393) with a strong positive correlation to large scale barren areas (5BARRENAR, r = .400) (Table 6). Birds with a relatively strong positive correlation to this axis (Table 4, Grasshopper Sparrow, Sprague's Pipit, and Chestnut-collared Longspur) are associated with sites that have relatively large barren acreages and lower precipitation within 5,000 m with low sage cover at the local scale. Barren acreages are typically concentrated in steeper areas with more erosion-created landscape features. Higher landscape precipitation may mean more forests and more productive vegetation growth in the general area.

Many landscape variables were derived from USGS GAP land cover data. That these variables often proved to be stronger predictors of breeding bird habitat choice than vegetation variables we directly measured at the site is significant given the nature of the GAP data. Developing regional animal-habitat models is an important use of GAP data (USGS National Gap Analysis Program 2005), but application of this data in habitat analysis requires an understanding of the errors inherent in data derived from classified satellite imagery (Fleming et al. 2004). The draft USGS GAP (GAP Analysis Project) land cover map data used to develop many of the GIS variables is the second generation of GAP data and is newly available for Montana. While GAP data provides an accuracy assessment of the Ecological System types used as classification units, there is no information on the spatial distribution of errors (Fleming et al. 2004). Typically, these remotely sensed data products are most useful in providing a regional or national perspective on land cover; applicability decreases

as the focus landscape becomes smaller. However, in our study, GAP-derived variables, especially at the 5,000 m scale, often proved to be strong predictors of SOC breeding bird presence. The implication is that, despite inherent inaccuracies in GAP remotely sensed classification data, these landscape factors are of considerable importance for the breeding SOC birds.

Despite data caveats of small sample size for some species and a relatively extended sampling season, results suggest that any management of grassland bird species will benefit from both landscape and site considerations. The importance of site or landscape factors varies with individual species, site factors may be more important for some species (e.g. Brewer's Sparrow), or landscape factors for others (e.g. Sprague's Pipit). For other species, there is a more balanced response to site and landscape factors.

# Conclusions and Management Considerations

Several considerations concerning the management of prairie landscapes in southeastern Montana are apparent, despite limitations in the methods we employed in our study. We suggest that a diversity of habitat conditions at multiple scales need to be maintained to support the full spectrum of bird species using the region, echoing other studies showing that prairie bird species occupy gradients of vegetation structure and composition (e.g., Paige and Ritter 1999, Madden et al. 2000) and that their occurrence may be dependent upon features at quite different landscape scales (Knick and Rotenberry 2000, Bakker et al. 2002, Cunningham and Johnson 2006).

Fire and grazing are considered important tools for creating and maintaining the diversity of vegetation structure in grasslands and shrublands (Paige and Ritter 1999, Madden et al. 2000, Askins et al. 2007). However, in a companion study (Cooper et al. 2007) we found that annual non-native weedy grasses, especially field brome (formerly Japanese brome), increased after prescribed or wildfire burns and maintained this increase for many years after burning in this study area. Our results indicate that many bird species will avoid sites where grass density and height (especially of exotic annual grasses) become too great. In our case, this was largely due to presence of cheatgrass and field brome. Cheatgrass readily invades disturbed sites, such as areas where livestock churn up soil and biological soil crusts, and graze native bunchgrasses (Leopold 1941, Paige and Ritter 1999). Limiting the spread of exotic annual grasses is highly desirable for the conservation of grassland and shrubland birds, which have a variety of habitat requirements if they are to coexist. Grazing can be used to promote a mosaic of vegetation structure and growth of native grasses and forbs, depending on current condition and plant composition of the range. Where cheatgrass and native perennial grasses are mixed, grazing during the dormant period may favor the perennial species (Vallentine and Stevens 1994). Wildfires should probably be suppressed in areas prone to invasion by cheatgrass, because wildfires fueled by cheatgrass are converting shrublands into expanses of exotic annual grasses (Knick and Rotenberry 2000). If controlled fire is used as a tool, it should be done on a small scale and timed to avoid midsummer, which favors cheatgrass; early spring and late fall are preferred times for controlled burns because the soil is moist and native grasses are dormant (Paige and Ritter 1999). Fire will also virtually eliminate Wyoming big sagebrush in this area with recovery times well over a century (Cooper et al. 2007).

Minimizing fragmentation of extant habitat is also a primary consideration. Many prairie species, such as Baird's Sparrow, Sprague's Pipit, Brewer's Sparrow, and Greater Sage-Grouse, which are Montana Species of Concern (Montana Natural Heritage Program and Montana Fish, Wildlife and Parks 2006), are area sensitive and negatively impacted by fragmentation of grasslands or shrublands (Knick and Rotenberry 1995, Johnson and Igl 2001, McMaster and Davis 2001, Walker et al. 2007). However, different sources of fragmentation may influence bird responses differently. For example, birds may respond to urban development and agricultural use quite differently than the alterations associated with energy development; even the type of energy

development (e.g., wind farm versus coal-bed methane) is expected to impact bird species in different ways. Probably the best rule of thumb (Paige and Ritter 1999) is to manage for no net loss of grassland and shrubland habitats, and to maintain native vegetation communities in large and continuous stands wherever possible.

We found that prairie grassland and shrubland SOC birds varied in their response to site and landscape habitat factors in southeastern Montana when selecting sites in which to breed. A more exact quantification of the relative importance of these factors for specific bird species will require additional breeding bird data and an analysis that includes relevant habitat factors within distances at least as large as 5,000 m. However, our evidence was clear that both site and landscape factors are important, and that GAP-derived variables, especially at the 5,000 m scale, were important, and sometimes proved to be stronger predictors of breeding bird habitat choice than vegetation variables we directly measured at the site. Managers concerned with declining prairie SOC birds in our study area may wish to apply species-appropriate site vegetation management with knowledge of landscape characteristics and current GAP land cover maps. Results suggest that with more breeding bird data GIS models can be developed that will allow managers to focus management and conservation actions in the most appropriate landscapes for SOC birds.

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